

ACTIVITY REPORT

January 2001



**Natural
Gas &
Oil
Technology
Partnership**

bringing department of energy national laboratories capabilities to the petroleum industry

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November
Oil and Gas Recovery Technology
Drilling, Completion, and Stimulation Technology
Diagnostic and Imaging Technology

February, April, June, August, October, December
Upstream Environmental Technology
Downstream Environmental Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: <http://www.sandia.gov/ngotp/>

Oil and Gas Recovery Technology

Improved Waterflooding Through Control of Brine Composition and Other Factors

(BP Amoco, U of Wyoming, and INEEL)

Highlight:

- Core from five wells selected for laboratory testing.

INEEL researchers have shown that by injecting diluted reservoir brine in laboratory corefloods, waterflood oil recovery is significantly increased under certain conditions. We are currently working with Inland Resources, which operates an oil field in the Uinta basin of Utah, to determine if their field is applicable to this improved recovery process. The reservoir fits our preliminary screening criteria for applicability of the process. Fresh water is being injected along with produced brine commingled with the fresh injection water after breakthrough. This provides a potential opportunity to test the process in the field by controlling the locations where the commingled brine is used.

Water samples collected from the Monument Butte field were analyzed to determine the composition of the formation brine and injection water. Laboratory corefloods using Monument Butte crude oil, Monument Butte sandstone, and simulated Monument Butte brine are planned to ascertain the applicability of modifying the injection brine to improve oil recovery of the waterflood.

Berea sandstone cores are being prepared to determine if the process can be scaled-up from the 3-in. cores to larger cores and eventually to a field scale. Waterfloods on 3-in. cores are set to begin in February. A Minnelusa asphaltic crude oil (Gibbs) was selected for use in these experiments.

The University of Wyoming has investigated the imbibition of liquid into clean and dry Berea sandstone cores. The size, shape, and boundary conditions of the core as well as the viscosity of the liquid each have an effect on imbibition. The generalized scaling equation used to identify imbibition behaviors in refined oil/brine/rock systems is not applicable to experimental data from air/refined oil/rock systems. This is probably due to the large viscosity differences between the two fluids and the compressibility of the air. An empirical scaling equation has been verified by experimental data for air/refined oil/rock systems. The empirical scaling equation uses a modified characteristic length and a new term regarding the viscosities of the nonwetting and wetting phases.

Development of a New-Generation Petroleum Reservoir Simulator

(BP, Chevron, Conoco, Cray Research, IBM, Landmark Graphics, Schlumberger-GeoQuest, Scientific Software-Intercomp, Texaco, Unocal, UT-Austin, and ANL)

Report not received.

Fluid Identification Acoustic Logging Tool

(BP Amoco, CGG, Chevron, Conoco, Landmark Graphics, Mobil, Schlumberger, Shell, Smedvig, Texaco, Unocal, Ward Petroleum, Western Atlas, and LANL)

LANL researchers continue to refine the automatic tracking electronics design that allows real-time measurement of oil composition. The system has a sensitivity of 0.2 parts per million in resolving sound speed under static condition. However, the system has not been tested under flow conditions.

The previous design involved acoustic-phase separation of gas from the fluid in a multi-phase flow system, which was intended to make measurement on the fluid composition and gas content separately but simultaneously. The swept-frequency acoustic interferometry (SFAI) technique shows degraded performance when the gas content in a multi-phase flow system is too high. We are working on an integrated system that has the possibility of deriving all the

required information acoustically and rely on a separate capacitive measurement for the gas volume fraction measurement.

LANL briefed its industry participant, DeepLook, on the project's status in Houston, January 16, 2001. The feedback was very valuable in deciding on a future test phase for this project.

High-Resolution Reservoir Characterization Using Seismic, Well, and Dynamic Data

(BP Amoco, Chevron, Exxon, Oxy, Phillips,
RC2, Texaco, Western Geophysical, Texas A&M, and LBNL)

Report not received.

Measuring Sucker Rod Pump Parameters Downhole

(Harbison-Fischer, Yates Petroleum,
UT-Austin, Texas Tech University and SNL)

Highlight:

- Two papers written.

The prototype downhole instrumented pump is being assembled for testing in Austin.

Spin-offs of the original scope of this project continue. Video and data were recorded of two traveling valves in action. The video shows that the two valves do not necessarily behave (open, chatter, etc.) the same. A method for measuring the pressure between the valves is being developed. Examination of data suggests there maybe two distinct types of valve chatter. The first must occur when the valve opens to balance flow with plunger movement. The second occurs when the flow rate is so high that the ball is slung around by turbulent flow. The first is observed in the work at the University of Texas. The latter was observed in previous work at SNL. Understanding the nature of chatter is a first step to mitigating the damage caused by chatter.

Two papers were written. "Laboratory Instrumented Sucker-Rod Pump" will be presented at the Society of Petroleum Engineers Production Operations Symposium in March 2001. "Analyses of Laboratory, Instrumented Sucker-Rod Pump Data" will be presented at the Southwestern Petroleum Short Course in April 2001.

Formation Logging Tools for Microboreholes

(DeepLook Collaboration, Texaco, and LANL)

Highlight:

- Discrepancy in performance noted and corrected.

Apparent, but not physically possible, shifts in gamma-ray spectral peaks were recorded by both commercial and microhole tools were noted if casing sizes were changed in the test setup described in previous reports. It was learned that one casing was heavily magnetized and, consequently, the performance of the photomultipliers in both of the tools was affected.

Magnetic shielding resolved the discrepancy. A new set of measurements was initiated to learn if the respective intensity of the peaks was also affected, in which case, earlier measurements of the relative performance of the tools will be repeated.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling

(Mobil,
Schlumberger, UT-Austin, and SNL)

Highlight:

- Modified JAS3D to improve calculation of porosity changes.

Recently SNL modified the way in which JAS3D calculates porosity changes from changes in stress/strain. The code now calculates changes in relative density (and hence porosity) from the total strain. (Prior to this point we were calculating these updates from the change in inelastic strain only.) This new quantity (total volume strain) causes a bigger change in reservoir pore volume as either elastic or inelastic strain accumulates at every time step. We observed that the convergence behavior of the flow simulator (IPARS)

changes when these total volume strain-calculated porosity changes occur. We plan to implement a modification to the Jacobian and conjugate gradient preconditioner to allow the flow simulator to more accurately predict these large changes and to robustly handle porosity and permeability changes coming from total strain change. In addition, we are assembling a suite of problems to help us verify the staggered coupling scheme used in the IPARS/JAS3D code against a tightly coupled oil company research code for flow and geomechanics. This suite of problems will include both analytical and computational solutions.

Semiautomatic System for Waterflood Surveillance

(Aera Energy LLC, Atlantis Scientific, Chevron, Electromagnetic Instruments, Integrated Micro Instruments, and LBNL)

Report not received.

Drilling, Completion, and Stimulation Technology

Evaluation of Concepts and Components for Directional Underbalanced Drilling and Microdrilling

(DeepLook, Fleet Cementers, Maurer Engineering, Mobil, Texaco, U of Tulsa, and LANL)

Report not received.

Real-Time Coiled Tubing Inspection System

(Quality Tubing and INEEL)

Highlight:

- Hall probe system completed and used to test samples.

Nine samples of 1.25-in. x 0.109 QT800 coiled tubing were fatigue tested in the University of Tulsa Fatigue Laboratory using the coiled tubing fatigue testing fixture. Four of the samples were plain, and the other five were coated with magnetic strips applied by INEEL. To compare the influence of the coating on fatigue strength, samples were cycled between a straight position and a curved position with a 48-in. radius of curvature, while maintaining constant internal pressure. Cycling continued until failure (defined by loss of internal pressure). Two pressure levels were examined. One corresponded to an average hoop stress of about 4% of the nominal yield strength (low pressure), and the other corresponded to 40% of the yield strength (high pressure). These pressures were nominally 638 psi and 6388 psi, respectively.

The magnetic strips appear to have adversely influenced the fatigue strength during low-pressure cycling, but the opposite appears true for high-pressure cycling. For the low-pressure tests, the average life for the coated samples was 27% lower than the average for the baseline tests. The average life from two high-pressure coated tests was 23% higher than the average from the two baseline tests.

Due to the scatter inherent in this type of testing, and the small sample sizes, it is not possible to ascribe any probabilistic certainty to these data. The life reduction imposed on the low-pressure samples is reasonable, because the surface is scored to prepare for coating. It is not surprising for the effect to be less influential at high-pressure, but it cannot be concluded that "coating improves life for high pressure service" in general. One sample (MC4) showed a significantly longer life, and the reasons for this are being evaluated.

Perforation Dynamics in Geological Media

(Columbia Gas Transmission, Halliburton, National Fuel & Gas Supply, Panenergy, and LLNL)

Report not received.

Drill Cuttings Injection Field Experiment

(BP Amoco, Chevron, Exxon, Gas Research Institute(GRI), Halliburton Energy Services, Hughes Christensen, MSD, Pinnacle Technologies, Schlumberger, Shell, and SNL)

Project is in close-out phase with reporting and technology transfer under way

Seismic Stimulation for Enhanced Production of Oil Reservoirs

(AERA Energy, Applied Seismic Research, Chevron, Conoco, Fluidic Technologies, Halliburton, Marathon, OGC Management, PerfClean, Phillips, Piezo Sona-Tool, Texaco, UC-Berkeley, LANL, and LBNL)

Highlight:

- Project close-out efforts begun.

The project is entering its close-out phase. No new experiments are planned. Remaining tasks include completing ongoing field monitoring of the Lost Hills test, analysis of laboratory experimental data, and assessment of current modeling capabilities. Plans for publication of all relevant project results and for a final general meeting are under discussion. Possibilities for future support of this work outside of DOE/FE are being considered.

In-Well Imaging and Heating: Multiple-Use Well Design

(Aera Energy LLC, Chevron, SteamTech Environmental Services, and LLNL)

LLNL continues to evaluate different established petrophysical relationships to interpret the changes in electrical properties observed during stimulation, particularly with respect to production criteria. The team met with industry representatives to discuss final field verification for imaging and interpretation, which will be conducted in the spring.

Refined final models have been run for the different ohmic heating simulations for input into imaging forward models. Calibration runs are under way to assess combined ohmic heating/imaging for comparison with steam simulations.

3D Analysis for Induction Logging in Horizontal Wells

(BP Amoco, Chevron, Conoco, Electromagnetic Instruments, Exxon, Halliburton, Mobil, Phillips, Schlumberger-Doll, Shell, Texaco, Unocal, Western Atlas, and SNL)

Highlights:

- Localized inversion code in testing phase.
- Matrix-free version of the 3D finite-difference modeling software developed.

In the last several weeks, efforts focused on three primary objectives:

- investigation of borehole effect,
- localized inversion induction log datasets, and
- optimization of the 3D modeling software.

While borehole research is still in the early stages, development of a localized inversion code has progressed to the testing phase. Analysis of induction log data is expected to commence shortly. SNL has also developed a matrix-free version of the 3D finite-difference modeling software. This greatly reduces the amount of computer memory required by the software and therefore allows the use of inexpensive PCs to solve relevant problems in horizontal-well induction logging.

The matrix-free 3D code has also been ported for use on distributed memory parallel clusters like the Linux-based Beowulf cluster formation. Using the MPI parallelization library, each node of the parallel cluster independently computes

a single logging point. This admits a minimum of inter-processor communication. Therefore, nearly optimal performance in scaling is achieved with this cluster size.

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Chevron, INEEL, and LBNL)

Highlights:

- Feasibility report completed.
- Savoy Field Research Facility selected for prototype testing.
- Constructed Prototype.

No work was performed on this project during December 2000 and January 2001. Work will resume in May 2001 with modeling of the field data collected in November 2000. Continued development of the prototypes for additional field testing will also resume in May 2001.

Acoustic Telemetry (MWD)

(ABB, Passband Downhole Communications,
Electroacoustics Research Laboratory, and SNL)

Highlights:

- Signal processing algorithm under development.
- Surface receiver system under development.

SNL is making minor modifications to the downhole telemetry system to strengthen its components against vibration with expectations to complete the task and schedule the first field test of the prototype within the next two months. We plan to deploy the prototype in a well to a depth of approximately 10,000 ft. It may be subjected to light drilling. However, we have not built the rotating receiver sub yet. We will only be able to receive data during periods when the drill string is not rotating. Currently, we are reviewing contract proposals to build the receiver sub, which will be mounted at the top of the kelly. The receiver sub will sense the acoustic waves in the drill string and use a commercial radio frequency (RF) modem link to transfer the data off of the rotating kelly on to a PC.

SNL has also initiated the development of signal processing algorithms that can reduce noise, suppress echoes, and decode the modulated acoustic signal captured by the receiver sub. We are testing these algorithms on acoustic data obtained from integration tests of the downhole prototype at SNL's surface facility. These algorithms have preformed surprisingly well. We are able to acquire data in excess of 20 baud in this relatively short 1400-ft drill string, which riddles the acoustic path with numerous echoes. Even on a standard Windows NT operating system, the algorithms appear capable of processing and decoding the raw data at twice the rate that the data is acquired.

Development of Chemically Bonded Ceramic Borehole Sealants

(GPRI, ANL, and LANL)

Highlights:

- Consistency tests performed on candidate formulations.
- Tests established that Ceramicrete is a suitable borehole sealant.

Two trips were made to Chevron's Cement Laboratory to test the Ceramicrete material. Chevron's technical staff completed additional test on materials sent by ANL.

Consistency tests conducted by Chevron established that the Ceramicrete formula meets American Petroleum Institute Standards for borehole temperatures and pressures up to 150° F and 6160 psig. The following observations were made during these tests:

- Magnesium oxide, a prime ingredient in the binder that was pretreated at ANL, performed much better than a similar powder that is available commercially.
- Boric acid had a retarding effect when the ash contained calcium. Ash with very low calcium does not exhibit a retarding effect with boric acid.
- Boric acid decomposed at 120° F and exhibited no retarding effect at high temperatures.

Future tests will include determine the extent of expansion (contraction) of Ceramicrete during setting and curing, its bond strength to downhole materials, compressive and flexural strengths, fracture toughness, etc. Efforts will also be directed toward developing formulations that provide a pumping time in excess of three hours at higher temperatures and pressures.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring (DeepLook, Phillips, Texaco, and LANL)

San Ysidro Drilling Demonstration

Highlights:

- Concept for real-time rheometry measurement method demonstrated.
- First attempt to complete the 600-ft microhole at San Ysidro unsuccessful

The third attempt to run in a 1.66-in. OD PVC casing to a depth below the flowing aquifers was successfully completed by running the casing inside NQ drilling rods and removing the rods. Attempts to circulate and condition the hole for cementing were plagued by hole collapse or caving. After finally establishing good circulation at moderated pump pressure, neat cement was mixed and pumped down the casing. The pump pressure increased and the flow stopped just as the cement started up the annulus. It is planned to wash over the 1-1/4-in. PVC casing with drill rods when weather conditions improve.

Hydraulic Calculations

A concept for a real-time fluid viscometer that is compatible the micro-drilling circulation system and the PC data acquisition and control system was demonstrated with three flow rate, pressure drop datasets. It successfully calculated the correct rheology for an ideal theoretical data set and the ideal dataset with up to 5% background noise added. It also produced the rheologic constants for one real data set that were within 5% of the values calculated with six-point Fann viscometer measurement. The concept presently assumes a yield-power-law (Herschel-Buckley) fluid. It is believed that it can be adapted to allow other fluid with some of the other three-parameter models if the yield-power-law model does not represent microdrilling fluid adequately.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation

(Input/Output, Texaco, and LANL)

Highlight:

- Microhole completion work yet to be completed.

LANL ran and cemented 1-5/8-in. PVC casing into a 600-ft microhole that had been drilled for testing of the 7/8-in. microhole seismic array. During cementing no returns were observed at the surface although artesian flow up the casing annulus had ceased. Operations were terminated for the holidays. The casing plan filed with the State Engineers Office required evidence of cementing to the surface. Following resumption of operations, it was learned that only the lower 200 ft of the well had been properly cemented. A combination of lost-circulation material injected in advance of the cement and swelling clays prohibited cement return to the surface. The PVC casing was washed over and retrieved from the well in preparation for a second attempt to cement the well.

Development of Single-Well Seismic Imaging Technology

(BP Amoco, Chevron, Conoco, Exxon, OYO Geospace, P/GSI, Phillips, Schlumberger, Shell, Texaco, TomoSeis, Unocal, Western Atlas, Stanford, LBNL, SNL, and INEEL)

Report not received.

Large Downhole Seismic Sensor Array

(Chevron, Conoco, Exxon, OYO Geospace, Shell, Texaco, U of Arkansas, and INEEL)

Highlight:

- Construction of demonstration prototype begun.

The total passive design was completed and tested in December 2000, but two of the three receiver channels failed to activate. However, the working channel demonstrated the array's capability. The electronics were modified to improve durability of the array. Attempted testing in early January 2001 resulted in a complete failure of the computer. The array functioned with all channels. Response was poor for the horizontal phones, while the vertical phone worked without problems. It was first believed that previous failures were related but a review of the design revealed that some of the initial concepts were not incorporated during fabrication. The initial design placed the horizontal phones normal to the casing wall, while the assembly positioned them tangent to the wall. This has now been changed and will be tested in February 2001.

Detailed drawings will be provided as part of the output documentation from the project and will include the design of the compact, three-component housing.

Improved Prestack Kirchhoff Migration for Complex Structures

(Conoco, Cray/SGL, Golden Geophysical, Kerr-McGee, Mobil, Shell, and LANL)

Report not received.

Locating Geopressured Hydrocarbon Reservoirs in Soft, Clastic Sediments Through Identifying Associated Pressure Seals

(Conoco and INEEL)

Highlight:

- Reservoir and synthetic modeling completed.

Discussions concerning project results were held with industry. Arrangements were made to present final results to four companies. The meetings are scheduled for the first week of February 2001. These meetings will determine interest in licensing technologies that have been developed through work performed on this project.

Testing Advanced Computational Tools for 3D Seismic Analysis Using the SEG/EAGE Model Dataset

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Edison Chouest Offshore, Exxon, GECO-Prakla, Golden Geophysical, Kerr-McGee, Marathon, Mitchell Energy, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Houston Advanced Research Center/Rice, Stanford, UC-Davis, U of Houston, LANL, LLNL, and ORNL)

Highlight:

- Close-out efforts planned for imaging of physical model data.

The final technical task of this project is to select 3D image subsets of the marine survey and vertical cable datasets collected for the subsalt physical model. Plans for selecting appropriate regions of the model to image were devised. The selections will be based on data quality, regions of physical importance in the model, and reliability of the velocity model, which varies throughout the physical model. The results of this effort will be used to assess directions for future proposed physical model designs.

Integrated Reservoir Monitoring Using Seismic and Crosswell Electromagnetics

(Chevron, Electromagnetic Instruments, TomoSeis, LBNL, and SNL)

Report not received.

Frequency-Dependent Seismic Attributes of Fluids in Poorly Consolidated Sands

(Baker-Atlas, Chevron, TomoSeis, Vastar, and LBNL)

No report received.

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, Conoco Fairfield Industries, GX Technology, Marathon, Texaco, Unocal, and SNL)

Highlights:

- Parallel computational implementation of the time-variant model updating scheme well underway
- Time-variant and time-invariant equations derived.

The solution to the (nonlinear) full waveform seismic inverse problem involves continued updating of an initial estimate of a 3D earth model. This will continue until an acceptable match is obtained between observed and predicted (i.e., computed) seismic data. An extensive theoretical effort based on the seismic reciprocity principle has identified two linear equations that can conceivably be used to determine the updates required for an elastic earth model. Both a time-variant equation and a time-invariant equation have been derived. The characteristics of each are currently being investigated, particularly with regard to ease of computational implementation, memory demand, and algorithm execution speed. Although the time-invariant updating expression bears some similarity to existing full waveform inversion approaches, the time-variant alternative appears to be novel. A parallel computational implementation of the time-variant model updating scheme is well under way. This algorithm involves the use of sparse matrix/vector storage and manipulation technology to solve the large system of linear algebraic equations for the earth model updates.

High-Speed 3D Hybrid Elastic Seismic Modeling

(Burlington Resources, GX Technology, and LBNL)

Report not received.

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Exxon, GECO-Prakla, Marathon, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Stanford, U of Houston, LANL, and LLNL)

Highlights:

- Modeling capabilities being expanded and licensed.
- Common image gathers computed for amplitude vs. offset analysis.
- Testing begun on narrow-azimuth migration.

The project team is in the final stages of licensing its 3D seismic modeling capabilities to an oil service provider. Based on needs expressed by industry representatives at the last project-wide meeting (September 2000), the team is pursuing the implementation of additional physics into its modeling capabilities. In particular, this includes anisotropic functionality. We have begun the task of investigating wide-aperture propagation through and below a subsalt model. We have developed a technique that creates angle gathers with amplitudes that correctly indicate the changes of reflectivity as function of incidence angle. The method is used after wave-equation migration, and is equivalent to a radial trace transform in the Fourier transformed offset image gathers.

After the successful testing of narrow-azimuth migration on a $V(z)$ model, we started testing the technique on the SEG/EAGE salt dataset. Preliminary results are promising, but more conclusive results require running on the cluster of Linux computers that are soon to be installed at SEP.

The Partnership Office

Upstream Technology Areas

The Partnership has stepped into the new year. The funding recommendations for the three upstream technology areas (Oil and Gas Recovery; Drilling, Completion, and Stimulation; and Diagnostic and Imaging) have been completed by the Partnership Office. These recommendations are being reviewed and finalized by the National Energy Technology Laboratory (NETL) and its branch the National Petroleum Technology Office (NPTO).

The Partnership has another note of interest and request for comment. As the Partnership has added new technology areas over the last five years, these areas have been guided by industry panels. These panels through workshops and other venues have defined the industry needs in the new technology areas. In turn, the panels have prioritized the needs. The prioritized list has provided the

focus of the subsequent Partnership proposal call in that technology area. The Partnership Office has received suggestions that we implement a similar process in the three traditional (Oil and Gas Recovery; Drilling, Completion, and Stimulation; and Diagnostic and Imaging). The Partnership has started to analyze how this may be done and what may be the effects on the technology areas. As always, we request your comments and suggestions.

Upstream Environmental Technology

An industry panel reviewed Upstream Environmental projects at the NPTO offices in Tulsa on January 17, 2001. Due to lower than expected appropriations for the area, new start proposals were not solicited for FY01. Panelists' review comments were provided to lead laboratories for summary. A funding recommendation letter to NPTO should be sent in early February.